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DOMESTIC PREPAREDNESS PROGRAM TESTING OF HAZMATCAD DETECTORS AGAINST CHEMICAL WARFARE AGENTS SUMMARY REPORT

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13. ABSTRACT (Maximum 200 words) This report characterizes the chemical warfare (CW) agent detection potential of the commercially available HAZMATCAD. Three HAZMATCAD instruments were tested against HD, GB, and GA vapors under various conditions. This report is intended to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of the HAZMATCAD.			
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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness. This work was started in November 2000 and was completed in September 2001.

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SUMMARY REPORT

1. INTRODUCTION

The Department of Defense (DOD) formed the Domestic Preparedness (DP) Program in 1996 in response to Public Law 104-201. One of the objectives is to enhance federal, state, and local capabilities to respond to Nuclear, Biological, and Chemical (NBC) terrorism incidents. Emergency responders who encounter either a contaminated or a potentially contaminated area must survey the area for the presence of either toxic or explosive vapors. Presently, the vapor detectors commonly used are not designed to detect and identify chemical warfare (CW) agents. Little data are available concerning the ability of these commonly used and commercially available detection devices to detect CW agents. Under the DP Expert Assistance (Test Equipment) Program, the U.S. Army Soldier and Biological Chemical Command (SBCCOM) established a program to address this need. The Applied Chemistry Team (ACT), Aberdeen Proving Ground, Edgewood, Maryland, performed the detector testing. ACT is tasked with providing the necessary information to aid authorities in the selection of detection equipment applicable to their needs.

Reports of the instrument evaluations are posted in the Homeland Defense website (http://www2.sbccom.army.mil/hld/ip/) for public access. Instruments evaluated and reported in 1998, 1999, and 2000 include:

- MiniRAE plus from RAE Systems, Inc.
- Passport II Organic Vapor Monitor from Mine Safety Appliance Co.
- PI-101 Trace Gas Analyzer from HNU Systems, Inc.
- TVA 1000B Toxic Vapor Analyzer (PID and FID) from Foxboro Co.
- Draeger Colorimetric Tubes (Thioether and Phosphoric Acid Ester) from Draeger Corp.
- Photovac MicroFID detector from Perkin Elmer Corp.
- MIRAN SapphIRe Air Analyzer from Foxboro Co.
- MSA Colorimetric Tubes (HD and Phosphoric Acid Ester) from Mine Safety Appliances Co.
- M90-D1-C Chemical Warfare Detector from Environics OY, Finland
- APD2000 Detectors from Environmental Technologies Group, Inc.
- SAW MiniCAD mkII from Microsensor Systems, Inc
- UC AP2C Monitor from Proengin Inc., France
- ppbRAE Photo-Ionization Detector from RAE Systems, Inc.
- SABRE2000 detector from Barringer Technologies, Inc.
- CAM (Type L) from Graseby Dynamics Ltd., UK

In 2001, the evaluation of instruments continued using test items that were loaned to the DP program by the respective manufacturers. Viable candidate instruments were required to pass a pre-screening test. In exchange, the instruments were evaluated under the DP protocol and the manufacturers were permitted to take data during the evaluations. Instruments evaluated included:

- Vapor Tracer System from Ion Track Instruments, Inc. (Wilmington, MA)
- HAZMATCAD from Microsensor Systems, A Sawtek Company (Apopka, FL)
- GC-MS/FPD with Dynatherm System from Agilent (Columbia, MD)
- Scentoscreen GC from Sentex Systems, Inc. (Fairfield, NJ)

Each of these evaluations will be reported separately. This report pertains to the evaluation of the HAZMATCAD from MicroSensor Systems.

2. OBJECTIVE

The objective of this report is to assess the capability and general characteristics of the HAZMATCAD SAW (Surface Acoustic Wave) instrument to detect CW agent vapors. The intent is to provide the emergency responders concerned with CW agent detection an overview of the detection capabilities of the instrument.

3. SCOPE

This evaluation is an attempt to characterize the CW agent vapor detection capability of the HAZMATCAD SAW sensor based detection instrument. Due to time and resources limitations, the agents used were limited to tabun (GA), sarin (GB), and mustard (HD). These were chosen as representative CW agents because they are believed to be the most likely threats. Test procedures follow the established DP Detector Test and Evaluation Protocol described in the Phase 1 Test Report.[1] The test concept was as follows:

a. Determine the minimum detectable level (MDL), the lowest concentration where repeatable detection readings are achieved for each selected CW agent. The current military Joint Services Operational Requirements (JSOR)[2] for point sampling detectors served as a guide for detection sensitivity objectives.

b. Investigate the effects of humidity and temperature on instrument performance.

c. Observe the effects of potential interfering vapors upon instrument performance in the laboratory and in the field.

4. EQUIPMENT AND TEST PROCEDURES

4.1 Detector Description.

Microsensor Systems, a Sawtek Company from Apopka, FL, is the manufacturer of the HAZMATCAD (http://www.microsensorsystems.com/hazmatcad.htm). Instrument description and operating procedures originate from the HAZMATCAD User's Guide.[3] The HAZMATCAD employs an array of three different Surface Acoustic Wave (SAW) sensors in a handheld Chemical Agent Detector (CAD). The SAW sensors respond to changes in mass of different polymer coated surfaces when a vapor sample flows over them. The array of SAW sensors provides a multi-pattern sensor response (fingerprint) that is unique to an agent or class of agents. The instrument will selectively produce an alarm (visible and audible) when the preset threshold levels for the CW agent detection algorithm are matched. The detector simultaneously detects blister and nerve agents, and differentiates detection by a corresponding H or G alarm.

Shown below is a digital photograph of the HAZMATCAD. Three units were loaned by Microsensor Systems for this evaluation and randomly labeled A, B, and C. At the beginning of the evaluation Units A and B were used, and Unit C was designated as a backup. However, Unit C was soon entered into the evaluation after problems were encountered with Unit B. Two units were tested throughout the evaluation depending on which two were usable on any given day.

HAZMATCAD

The HAZMATCAD can be operated in “Fast Mode” or “High Sensitivity Mode.” Fast Mode performs a sample analysis every 20 seconds. High Sensitivity Mode requires 120 seconds to perform a sample analysis. The HAZMATCAD sampling system collects and concentrates a vapor sample using a sample pump and a thermally desorbed concentrator. The desorbed sample passes over the SAW array causing vibration frequency changes corresponding to the changes in mass caused by the vapor sample. A microprocessor analyzes the sensor responses to determine when to alarm.

The HAZMATCAD runs on two lithium-ion (Li-Ion) rechargeable battery packs. Each unit is supplied with an external battery re-charger for the Li-Ion batteries. The units operated approximately 6-9 hours using their rechargeable battery packs. The battery packs had to be re-charged overnight before each day of testing. The unit weighs 0.64 kg (22 oz) including batteries. After installation of the battery packs, the unit is powered on by pressing the “ON” button. The HAZMATCAD is relatively easy to operate and automatically performs a self-diagnostic check, purges itself and begins analyzing for CW when powered on. According to the Users Manual, the instrument can operate in temperatures from -10 to +50 °C at non-condensing relative humidity (RH) levels of 0 to 95%.

The instrument status is indicated by the LED status display. Two green lights show that the unit is ‘ALL CLEAR’ and all subsystems are ‘SYS OK’. The blinking green ‘SYS OK’ light indicates proper electrical operation. The steady green ‘ALL CLEAR’ light indicates that no agents were detected. A yellow ‘LOW BATT’ indicator light illuminates when the batteries should be charged or replaced. The unit runs continuously and a blinking red ‘ALARM’ light indicates that an agent has been detected. The alarm status LED flashes at a rate relative to the alarm level. A low concentration threshold level will blink slower than a high level. At the same time, the alphanumeric LED display will flash ‘H’ or ‘G’ for the respective agent class, blister or nerve, and show the relative concentration level (low, medium or high).

4.2 Calibration.

No daily instrument calibration is required by the manufacturer to place the HAZMATCAD into operation, but a semi-quantitative simulant exposure (“confidence check”) is recommended. This confidence check was performed daily during this test. The manufacturer provided a Vapor Simulant Check Source, which is a Teflon vapor diffusion tube that contains DMMP (Dimethyl methyl phosphonate, a G-agent simulant). The Vapor Simulant Check Source allows a total system operational performance check of the instrument.

To perform the confidence check, the HAZMATCAD must be in Fast Mode and operating for at least 15 minutes with the appropriate green lights illuminated. Upon exposure to the Vapor Simulant Check Source, a ‘G’ alarm occurs at the end of the measurement cycle to confirm that the instrument is functioning correctly. The manufacturer states that no ‘H’ alarm confidence check is necessary and does not provide an ‘H’ simulant check source, therefore the ‘G’ simulant check was performed prior to all testing.

A reliability issue was observed as the units frequently needed to be powered on and off several times to operate correctly. In addition, the time to respond to the simulant check was inconsistent and occasionally required several minutes for a unit to respond correctly. The manufacturer claims to have made several improvements to the HAZMATCAD instruments for 2002 to correct the reliability problems and increase agent sensitivity.

4.3 Agent Challenge.

The agent challenges were conducted using the Multi-Purpose Chemical Agent Vapor Generation System[4] with Chemical Agent Standard Analytical Reference Material (CASARM) grade or highest purity CW agents available. Agent challenge followed successful instrument start up and confidence check. The vapor generator system permits testing of the instrument with humidity and temperature-conditioned air without agent vapor before challenging it with similarly conditioned air containing the CW agent vapor. This is to assure that the temperature and RH conditioned background air does not cause interference with the instrument.

The HAZMATCAD inlet is placed under the cup-like sampling port of the vapor generator and exposed to the conditioned air to establish a stable background before agent challenges. Agent challenge begins when the solenoids of the vapor generation system are energized to switch the air streams from conditioned air only to similarly conditioned air containing the agent. The time that the detector was exposed to the agent vapor until it alarmed was recorded as the response time. The agent challenge time was extended to 3-10 min if the detector did not produce an alarm in 2 min to observe its actual response over several additional analysis cycles. This was done to simulate actual application of these instruments. The time required after agent exposures until the instrument stopped alarming was recorded as the recovery time. Each unit was tested three times under each condition.

The instruments were each tested with the agents GA, GB, and HD at several concentration levels at ambient temperatures and 50% RH to determine the MDL with each agent. The effect of humidity on the detectors was also assessed by testing at ambient temperature with <10% and >90% RH. The effects of low temperature were assessed by testing at –10 °C for GA and GB, and 0 °C for HD. The effects of high temperatures were assessed by testing at +50 °C for GA, GB, and HD. Temperature extremes were selected based on the manufacturer's stated operating range using agent concentrations that approximated the MDL. Although HD freezes at approximately +15 °C, the calculated HD volatility of 92 mg/m^3 at 0 °C easily produces a vapor concentration higher than the 2 mg/m^3 JSOR detection criteria allowing the instrument to be evaluated at 0 °C.

4.4 Agent Vapor Quantification.

The generated agent vapor concentrations were analyzed independently and reported in both milligrams per cubic meter (mg/m^3) and parts-per-million (ppm) units in the data tables. The vapor concentration was quantified by utilizing the manual sample collection methodology[5] using the Miniature Continuous Air Monitoring System (MINICAMS®) manufactured by O. I. Analytical, Inc. (Birmingham, AL). The MINICAMS® is equipped with a flame photometric detector (FPD), and was operated in either phosphorus mode for the GA and GB agents or sulfur mode for HD.

This system normally monitors air by collection through sample lines and subsequently adsorbing the CW agent onto the solid sorbent contained in a glass tube referred to as the pre-concentrator tube (PCT). The PCT is located after the MINICAMS® inlet. The concentrated sample was periodically heat desorbed into a gas chromatographic capillary column for subsequent separation, identification, and quantification. For manual sample collection, the PCT is removed from the MINICAMS® during the sampling cycle and connected to a measured suction source to draw the vapor sample from the agent generator. The PCT was then re-inserted into the MINICAMS® for analysis. This "manual sample collection" methodology eliminated potential loss of sample along the sampling lines and the inlet assembly when the MINICAMS® was used as an analytical instrument. The calibration of the MINICAMS® was performed daily using the appropriate standards for the agent of interest. The measured mass equivalent (derived from the MINICAMS® chromatogram) divided by the total volume (flow rate x time) of the vapor sample drawn through the PCT produces the sample concentration that converts into milligrams/cubic meter.

4.5 Field Interference Tests.

The instruments were tested outdoors in the presence of common potential interferents such as the vapors from gasoline, diesel fuel, jet propulsion fuel (JP8), kerosene, Aqueous Film Forming Foam (AFFF, used for fire fighting), household chlorine bleach, and insect repellent. Vapor from a 10% calcium hypochlorite solution (HTH slurry, a chlorinating decontaminant for CW agents), engine exhausts, burning fuels, and other burning materials were also tested. The objective was to assess the ability of the instruments to withstand outdoor environments and to resist false alarming indications when exposed to the selected substances. In these tests, no CW agent was present.

The field tests were conducted outdoors at M-Field, Edgewood Area, Aberdeen Proving Ground, in July 2001. These experiments involved open containers, truck engines, and fires producing smoke plumes, which were sampled by the detectors at various distances downwind. The HAZMATCAD units were exposed to either the smoke or fume test plume to achieve moderate but not exaggerated exposures (e.g. 2-15 ft for vapor fumes and 6-30 ft for smokes).

Confidence checks were performed on each instrument at the beginning of each testing day and periodically between tests. During the field tests, both HAZMATCAD units were placed in Fast Mode (20 sec cycles) as recommended by the manufacturer's representative. The units were exposed to each interferent for at least 5 min for three trials when possible. Testing continued with the next challenge after the instruments were thoroughly recovered from prior exposure.

4.6 Laboratory Interference Tests

The laboratory interference tests were designed to assess the effect on the instruments of vapor exposure from potential interfering substances. The substances were chosen based on the likelihood of their presence during an emergency response by first responders. Additionally, the laboratory interference tests were conducted to assess the CW agent detection capability in the presence of these interferent vapors.

The HAZMATCAD units were tested against 1% of the headspace concentrations of diesel fuel, floor wax, AFFF, Spray 9 cleaner, Windex, toluene, and vinegar vapors. The units were also tested against 25 ppm NH_3 (ammonia). If the detector false alarmed at 1% concentration, it was tested at the 0.1% concentration of the substance. A dry air stream carries the headspace vapor of the substance by sweeping it over the liquid in a tube or through the liquid in a bubbler to prepare the interferent gas mixture. Thirty milliliters/minute or 3 ml/min of this vapor saturated air was then diluted to 3 l/min with the conditioned air at ambient temperatures and 50 %RH to produce the 1% or 0.1% concentration of interferent test mixture, respectively.

For the tests that included CW agent, the interferent test gas mixture was prepared similarly. The resultant stream of 3 l/min of either HD or GB vapor was used as a dilution stream to blend in with the 30 or 3 ml/min of the substance vapor to obtain the desired 1 or 0.1% mixture of the substance vapor in the presence of the CW agent concentration. The units were tested three times with each combination of agent-plus-interferent when possible.

5. RESULTS AND DISCUSSION

5.1 Minimum Detectable Levels.

The MDL for the HAZMATCAD instruments, Units A and B, are shown in Table 1 for each agent at ambient temperatures and 50% RH. The MDL values represent the lowest CW agent concentration that produced three consistent response alarms in three independent trials. Table 1 shows the range of response times observed for the MDL listed in both the "Fast Mode" and the 'High Sensitivity Mode." The MDL concentrations are expressed in milligrams per cubic meter (mg/m^3) with equivalent parts per million (ppm) values given in parentheses.

For comparison, the current military JSOR requirements for CW agent sensitivity for point detection alarms, the U.S. Army's established values for Immediate Danger to Life or Health (IDLH), and the Airborne Exposure Limit (AEL) are also listed in Table 1. Army Regulation (AR) 385-61[6] is the source for the IDLH and AEL values for GA and GB, and the AEL value for HD. The AR 385-61 does not establish an IDLH for HD due to concerns over carcinogenicity.

In High Sensitivity Mode, the HAZMATCAD units were able to detect HD, GA, and GB at the approximate JSOR and IDLH concentration levels with extended exposure times ranging from 69 to 252 seconds.

In Fast Mode, the units were inconsistent in their ability to detect either GA or GB at the JSOR or IDLH levels. Detection of HD in Fast Mode was slightly above the JSOR level for Unit A and slightly below the JSOR level for Unit B. Detection of GA in Fast Mode was slightly above the JSOR and IDLH values for Unit B and approximately at the JSOR and IDLH values for Unit A. The MDL of GB was 3 to 13 times higher than the JSOR and IDLH for both units. The HAZMATCAD was unable to detect to the AEL values for HD, GA, or GB.

Table 1. Minimum Detectable Level (MDL) and Average Response Time at Ambient Temperatures and 50% RH for the HAZMATCAD Units, With Requirements

AGENT and Detector Mode	Concentration in milligrams per cubic meter, mg/m^3, With parts per million values in parenthesis (ppm) And Response Times				
	Unit A MDL	Unit B MDL	JSOR*	IDLH**	AEL***
HD Fast Mode	2.48 (0.38) in 107-151 sec	1.49 (0.23) in 86-96 sec	2.0 (0.300) in 120 sec	N/A	0.003 (0.0005) up to 8 hr
HD High Sensitivity Mode	1.24 (0.19) in 186-229 sec	0.54 (0.08) in 170-226 sec			
GA Fast Mode	0.14 (0.02) in 33-139 sec	0.53 (0.08) in 79-199 sec	0.1 (0.015) in 30 sec	0.2 (0.03) up to 30 min	0.0001 (0.000015) up to 8 hr
GA High Sensitivity Mode	****0.21 (0.03) in 69-80 sec	0.14 (0.02) in 126-252 sec			
GB Fast Mode	0.60 (0.10) in 34-80 sec	1.39 (0.24) in 59-116 sec	0.1 (0.017) in 30 sec	0.2 (0.03) up to 30 min	0.0001 (0.000017) up to 8 hr
GB High Sensitivity Mode	0.39 (0.07) in 96-119 sec	0.39 (0.07) in 186-209 sec			

* Joint Service Operational Requirements for detectors.
** Immediate Danger to Life or Health values from AR 385-61 to determine level of CW protection. Personnel must wear full ensemble with SCBA for operations or full-face piece respirator for escape.
*** Airborne Exposure Limit values from AR 385-61 to determine masking requirements. Personnel can operate for up to 8 hr unmasked.
****Unit A was inconsistent and did not alarm at higher concentrations between 0.24 and 1.9 mg/m^3 .

No agent alarm responses occurred within the 20 sec manufacturer's claim for Fast Mode and most responses were greater than the claimed 120 sec response in High Sensitivity Mode. If the agent challenge was introduced at any time other than the beginning of the sampling cycle, it would not have a full sample analysis for that cycle. This prevented the response time from occurring within 20 sec in Fast Mode. In High Sensitivity Mode, a few alarms occurred within the first cycle of 120 sec, but most did not. Throughout the GA evaluations, the units often failed to produce alarm response at concentrations greater than the JSOR levels even with exposure times up to 8 min. Table 2 shows manufacturer's claims versus the MDLs found in Table 1.

Table 2. Minimum Detectable Level (MDL) and Average Response Time at Ambient Temperatures and 50% RH for the HAZMATCAD Units, With Manufacturer's Values

AGENT	Concentration in milligrams per cubic meter, mg/m3 , (with ppm in parenthesis) and response time in minutes							
	SAW A		SAW B		SAW C*		Manufacturer's Stated	
	MDL	Response Time (min)	MDL	Response Time (min)	MDL	Response Time (min)	Alarm Thresholds	Response time (min)
HD Fast Mode	2.48 (0.38)	1.5 to 2.5	1.49 (0.23)	1.5	MDL Not tested		0.4	<1
HD High Sensitivity Mode	1.24 (0.19)	3.0 to 4.0	0.54 (0.08)	3.0 to 4.0	2.13 (0.32)	3.0-5.0	0.09	2.0
GA Fast Mode	0.14 (0.02)	0.5 to 2.0	0.53 (0.08)	1.5 to 3.0	MDL Not tested		0.1 to 0.9	<1
GA High Sensitivity Mode	**0.21 (0.03)	1.0 to 1.5	0.14 (0.02)	2.5 to 4.5	MDL Not tested		0.02 to 0.25	2.0
GB Fast Mode	0.60 (0.10)	0.5 to 1.5	1.39 (0.24)	1.0 to 2.0	MDL Not tested		0.1 to 0.9	<1
GB High Sensitivity Mode	0.39 (0.07)	1.5 to 2.0	0.39 (0.07)	3.0 to 3.5	MDL Not tested		0.02 to 0.25	2.0

*Unit C was only brought into testing when Unit A or Unit B was inoperable.

**Unit A was inconsistent and did not alarm at the higher concentrations between 0.24 and 1.9 mg/m^3.

5.2 Temperature and Humidity Effects.

The HAZMATCAD units were tested under varied temperature and humidity conditions to assess their responses. Tables 3 through 8 list the respective responses of the units in both Fast and High Sensitivity modes at the various test conditions. The tests were conducted at ambient temperatures and approximately <10, 50, and >90% RH. The detectors were also tested at temperature extremes of 0 °C for HD, -10 °C for GA and GB, and +50 °C (HD, GA, and GB). The results listed represent multiple challenges with test units at agent concentrations between 0.1 and 30 mg/m^3.

Temperature extremes appear to affect the HAZMATCAD units. Units could not be powered on at –10 °C, therefore they were allowed to warm up at room temperature until they could be started. After successful start up in the warmer temperature, the units were returned to the chamber at –10 °C for testing. In cold temperatures, the units would not alarm to GA in either Fast Mode or High Sensitivity Mode. The units, on the other hand, were able to detect GB in both modes. GB was detected in the Fast Mode at a concentration that was a magnitude lower (better) than the MDL that was determined at ambient temperatures. Only Unit B in its Fast Mode was able to detect HD at 0 °C. The units required longer recovery times at the colder temperatures.

At high temperatures (50 °C), the units generally required longer time to respond to the Confidence Checks and sometimes would not alarm even after 3 min exposure to the simulant vapor. High temperature also affected the agent responses of the detectors. Unit A did not alarm in Fast Mode to HD up to concentrations of 13 mg/m^3 or to GB concentrations up to 4.3 mg/m^3. The HAZMATCAD units did not alarm at the MDLs determined previously in the initial testing summarized in Tables 1 and 2. Higher concentrations of CW agent vapors were necessary to trigger the alarms at 50 °C.

Testing was repeated at ambient and 50% RH since the sensitivity of the HAZMATCAD units appeared to fluctuate daily above and below the MDL values first determined at ambient temperatures. In High Sensitivity Mode, alarm response times even became longer as the CW agent concentration was increased. Inconsistencies of responses are seen in Tables 3- 8.

Humidity changes did not appear to have much of an effect on the HAZMATCAD except against GA where high and low humidity caused inconsistency and occasional no alarms.

Units A, B, and C often developed symptoms of contamination that caused long clear-down times. The units would also occasionally stick in the warm up mode, or show a false alarm for HD, GA, or GB, or would not yield the ‘Systems Ready’ light. Testing had to be conducted using whichever two units were working at the time. This explains why there are several ‘not tested’ entries in the following tables. Entries of ‘No Alarm’ in the tables refer to a unit that did not respond to the given agent concentration within a given response time.

Table 3. HAZMATCAD "Fast Mode" Responses to HD Vapor Concentrations

Temp. °C	%RH	HD Challenge Concentration		Unit A		Unit B		Unit C	
		mg/m³	ppm	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds
0	0	2.0	0.28	Not tested	Not tested	H Low/Med	33-86	Not tested	Not tested
0	0	3.4	0.47	Not tested	Not tested	H Low/Med	42-77	No alarm	Up to 3 min
50	50	Up to 13.08	2.18	No alarm	Up to 3 min	Not tested	Not tested	H Med/High	37-53
21	10	3.25	0.49	H Low/Med	34-123	H Low/Med	42-67	Not tested	Not tested
21	90	3.08	0.47	H Med	110-150	H Med	46-52	Not tested	Not tested
21	50	1.0	0.15	No alarm	Up to 4-7 min	H Low/Med	124-209	Not tested	Not tested
		1.5	0.23	No alarm	Up to 8 min	H Low	86-96	Not tested	Not tested
		2.0	0.30	H Med*	255-309	H Low/Med	29-68	Not tested	Not tested
		2.2	0.34	H Med	100-265	H Low/Med	38-62	Not tested	Not tested
		2.48	0.38	H Med	107-151	H Med	31-55	Not tested	Not tested
		3.0	0.46	H Med	129-161	H Med	38-46	Not tested	Not tested
		9.58	1.46	H Med	46-53	Not tested	Not tested	H High	52-61
		30.0	4.58	H Med/High	17-32	Not tested	Not tested	H High**	25-29

*1 out of 6 trials had no alarm after 3 min
**1 out of 3 trials had no alarm after 3 min

Table 4. HAZMATCAD "High Sensitivity Mode" Responses to HD Vapor Concentrations

Temp. °C	%RH	HD Challenge Concentration		Unit A		Unit B		Unit C	
		mg/m³	ppm	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds
0	0	3.4 Up to 20	0.48	Not tested	Not tested	No alarm	Up to 6 min	No alarm	Up to 3 min
50	50	4.1	0.68	H Med	245-305	Not tested	Not tested	H Low/Med	148-279
23	4	2.43	0.37	H Low/Med	109-249	Not tested	Not tested	H Med	174-233
21	95	2.50	0.38	H Med	175-264	Not tested	Not tested	H Med	197-255
16-22	50	.54	.08	No alarm	Up to 7 min	H Low	170-226	No alarm	Up to 6 min
		1.0	0.16	H Low	238-303	Not tested	Not tested	No alarm	Up to 6 min
		1.24	0.19	H Low	186-229	Not tested	Not tested	No alarm	Up to 6 min
		2.1	0.32	H Med	236-268	Not tested	Not tested	H Med	194-305
		Up to 2.63	0.39	H Med	272-339	Not tested	Not tested	No alarm	Up to 7-8 min

Table 5. HAZMATCAD "Fast Mode" Responses to GA Vapor Concentrations

Temp. °C	%RH	GA Challenge Concentration		Unit A		Unit B		Unit C	
		mg/m³	ppm	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds
-10	0	Up to 15.5	2.06	Not tested	Not tested	No alarm	Up to 4-6 min	No alarm	Up to 3-5 min
50	50	Up to 1.63	0.27	No alarm	Up to 3 min	Not tested	Not tested	No alarm	Up to 3 min
		2.65	0.43	G Med/High	30-43	Not tested	Not tested	G Med*	27
		3.2	0.52	G High	24-30	Not tested	Not tested	G High	12-19
19	8	Up to 0.74	0.11	No alarm	Up to 4-5 min	G High**	124-236	Not tested	Not tested
20	90	0.54	.08	G High	31-159	G High	50-196	No alarm	Up to 4-5 min
20	50	0.14	0.02	G Low/High***	33-139	No alarm	Up to 4-5 min	Not tested	Not tested
19		Up to 0.52	0.08	G Low/Med	68-291	No alarm	Up to 4-5 min	Not tested	Not tested
20		0.53	0.08	G Med	23-48	G High	79-199	Not tested	Not tested
19		0.75	0.11	G Med/High	79-169	G High	55-88	Not tested	Not tested
20		1.90	0.28	No alarm	Up to 3-4.5 min	G High	137-255	Not tested	Not tested

*2 out of 3 trials had no alarm in 3-4 min
**1 out of 6 trials had no alarm in 4 min
***1 out of 2 alarmed High G, but audible alarm only heard at Low G

Table 6. HAZMATCAD "High Sensitivity Mode" Responses to GA Vapor Concentrations

Temp. °C	%RH	GA Challenge Concentration		Unit A		Unit B		Unit C	
		mg/m^3	ppm	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds
-10	0	Up to 15.5	2.06	No alarm	Up to 6 min	No alarm	Up to 6-9 min	No alarm	Up to 6 min
50	50	Up to 0.44	0.07	No alarm	Up to 6 min	Not tested	Not tested	No alarm	Up to 6-7 min
		0.6	0.10	G Med	165-190	Not tested	Not tested	G Med	146-281
		0.8	0.14	G Med	115-139	Not tested	Not tested	G Med	242-357
21	9	.23	0.03	No alarm	Up to 6 min	G Med	115--135	Not tested	Not tested
21	91	0.19	0.03	G Med*	286	G Med**	117-167	Not tested	Not tested
20	50	0.14	0.02	No alarm	Up to 6 min	G Med	126-252	Not tested	Not tested
		0.19	0.03	No alarm	Up to 6 min	G Med	204-116	Not tested	Not tested
		0.21	0.03	G Low	69-80	G Med	172-193	Not tested	Not tested
		Up to 0.5	.07	No alarm	Up to 7 min	G Med/High	99-163	Not tested	Not tested
		1.90	0.28	No alarm***	Up to 6-8 min	G High	130-164	Not tested	Not tested

*2 out of 3 trials had no alarm in 6 min
**1 out of 3 trials had no alarm in 3 min
***1 out of 3 trials alarmed during conditioning

Table 7. HAZMATCAD "Fast Mode" Responses to GB Vapor Concentrations

Temp. °C	%RH	GB Challenge Concentration		Unit A		Unit B		Unit C	
		mg/m³	ppm	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds
-10	0	0.11	0.02	No alarm	Up to 6 min	No alarm	Up to 6 min	G Low	132-144
		0.36	0.06	G Low	29-60	G Low	40-50	G Low	35-46
50	50	Up to 4.3	0.81	No alarm	Up to 3 min	No alarm	Up to 3 min	No alarm	Up to 3 min
50	50	5.2	0.98	G Low*	161	Not tested	Not tested	G Low/Med	43-58
40	40	6.78	1.24	G Med*	14	Not tested	Not tested	G Med	19-31
50	46	11.26	2.13	G Med	19-148	No alarm**	Up to 3-5 min	G Low/Med	35-38
20	6	1.44	0.25	G Low	29-36	G Low	29-43	Not tested	Not tested
22	92	1.50	0.26	G Med	22-39	G Med***	91	Not tested	Not tested
19-23	50	0.60	0.10	G Low	34-80	No alarm	Up to 3 min	Not tested	Not tested
		1.39	0.24	G Low	20-23	G Med	59-116	Not tested	Not tested
		1.49	0.26	G Low/Med	18-36	G Med	101-196	Not tested	Not tested
		2.25	0.39	G Med	17-27	G Med	29-32	Not tested	Not tested
		6.16	1.07	G High	29-34	G Med/High	19-26	Not tested	Not tested

*2 out of 3 trials had no alarm in 3 min
** 2 out of 3 trials alarmed Low H
*** 2 out of 3 trials had no alarm in 3 min

Table 8. HAZMATCAD "High Sensitivity" Mode Responses to GB Vapor Concentrations

Temp. °C	%RH	GB Challenge Concentration		Unit A		Unit B		Unit C	
		mg/m³	ppm	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds	Alarm Reading	Response Time Range, seconds
-10	0	0.03	0.005	G Low	300-373	No alarm	Up to 7 min	G Low	192-381
50	50	2.3	0.44	No alarm	Up to 3 min	Not tested	Not tested	G Low	136-146
		5.04	0.95	G Low	88-197	Not tested	Not tested	G Med	104-171
40	40	6.78	1.24	G Med*	115-146	Not tested	Not tested	Not tested	Not tested
24	7	0.46	0.08	G Low	103-143	G Low	146-202	Not tested	Not tested
24	92	0.55	0.10	G Low	85-219	G Low	151-208	Not tested	Not tested
23-24	50	0.39	0.07	G Low	96-119	G Low	186-209	Not tested	Not tested
		1.0	0.17	G Low	62-95	G Med	117-173	Not tested	Not tested
		6.16	1.07	G Med*	130-132	G Med/High*	59-137	Not tested	Not tested

*2 trials only

5.3 Field Interference

The results of the field test interferent exposures are presented in Table 9. Field test conditions included ambient temperatures in the range of 26-31 °C with relative humidity levels between 53-76 %RH and gentle winds from 3 to 10 mph. Units A and B were used for the field interference evaluations as Unit C would not power up into ready mode. However, neither unit responded to any of the field interferents, i.e., there were no false alarms. Each unit was tested three times for 5-10 min exposures against the listed interferents with the exception of the doused wood fire and the burning tire. As shown, the units were tested only two times each due to the extremely dirty smoke from these two interferents. The dirty smoke contaminated the detectors and caused long recovery times.

Table 9. HAZMATCAD Units A and B Field Interference Testing Summary

Interferent	HAZMATCAD Units A and B in FAST MODE 5-10 min Interferent Exposures	
	Total Trials	Total False Alarms
Gasoline Exhaust, Idle	6	0
Gasoline Exhaust, Revved	6	0
Diesel Exhaust, Idle	6	0
Diesel Exhaust, Revved	6	0
Gasoline Vapor	6	0
Burning Gasoline Smoke	6	0
Diesel Vapor	6	0
Burning Diesel Smoke	6	0
JP8 Vapor	6	0
Burning JP8 Smoke	6	0
Kerosene Vapor	6	0
Burning Kerosene Smoke	6	0
Burning Cotton Clothes	6	0
AFFF (6%) Vapor	6	0
Clorox (6% Bleach) Vapor	6	0
HTH (10% calcium hypochloride) Vapor	6	0
Insect Repellent DEET	6	0
Burning Cardboard Smoke	6	0
Burning Wood Fire Smoke	6	0
Doused Wood Fire Smoke	4	0
Burning Tire Smoke	4	0

Post field tests against CW agents could not be performed because the HAZMATCAD units would not respond consistently to the simulant checks. Unit A did not respond at all to simulant in the post field test exposures. Units B and C were very slow to respond to simulant, and could not match the pre-field test responses for GB exposures. In fact, they would not alarm to GB at concentrations up to 3.0 mg/m^3. When rechecked with simulant, Units B and C would no longer respond. Since none of the HAZMATCAD units would respond properly to simulant or agent, further testing could not be completed after returning from the field tests.

5.4 Laboratory Interference Tests

Each test was repeated three times when possible. When a problem occurred at 1%, the interferent was lowered to 0.1% saturation and re-exposed to agent. Accurate responses to HD at 0.1% saturation of AFFF, Windex, and Spray Nine in both fast and high sensitivity modes were observed. The tests were completed at ambient temperatures and 50% RH, using CW agent concentrations above the determined MDL (2-4 mg/m3). Response times for agent-only detection were approximately equal to response times for interferent-plus-agent detections when the interferent did not cause a false alarm or interfere with CW detection.

Table 10 presents the results of exposing the instruments to several potential interferents with and without CW agent. Of the interferents tested, only toluene caused the units to produce false alarms, i.e. the units alarmed for agent when no agent was present. Exposure of the units to conditioned air containing either GB or HD in the presence of the potential interferents shows that units A, B, and C were unable to consistently detect and identify the CW agents in the presence of these interferents at 1% saturation.

After returning from the field tests, none of the HAZMATCAD units would respond properly to simulant or agent, and further laboratory testing with the interferents and agents could not be completed. For this reason, Table 10 has several 'Not Tested' entries.

Table 10. Results of Laboratory Interference Tests at Ambient Temperature and 50%RH

HAZMATCAD False Responses			HAZMATCAD Agent Plus Interferent Exposures Responses			
2-7 minutes Interferent Only Exposures			HD FAST Mode	HD High Sensitivity Mode	GB FAST MODE	GB High Sensitivity Mode
Vinegar	1%	No False Alarm	H Low/Med	H Med	No Alarm	Not tested
	0.1%	No False Alarm	Not tested		G Med*	G Med**
AFFF	1%	No False Alarm	H Low***	No Alarm	G Low/Med*	Not tested
	0.1%	No False Alarm	H Low/Med	H Med	Not tested	No Alarm*
Diesel	1%	No False Alarm	H Med/High	H Med	Not tested	
	0.1%	No False Alarm	Not tested			
Windex	1%	No False Alarm	No Alarm	Not tested	Not tested	
	0.1%	No False Alarm	H Med	H Med	Not tested	
Toluene	1%	H High	False Alarm****			
	0.1%	H Med*****	H Med/High	False Alarm	Not tested	False alarm
Spray Nine	1%	No False Alarm	No Alarm	Not tested	Not tested	
	0.1%	No False Alarm	H Med	H Med	Not tested	
Floor Wax	1%	No False Alarm	H Med	H Med******	Not tested	
	0.1%	No False Alarm	Not tested			
Gasoline	Not tested					
JP8	Not tested					
Bleach	Not tested					
25 ppm Ammonia	Not tested					

*Unit A only. Unit B did not respond to agent and could not be tested interferent + agent
** Unit B only. Unit A did not respond to agent and could not be tested interferent + agent
***Unit C only. Unit B did not respond to agent plus interferent
****Alarmed to Toluene, therefore cannot be tested against agent + interferent
*****False alarmed in High Sensitivity Mode only at 0.1%, therefore cannot be tested against agent + interferent at 0.1%
******Unit A only. Unit B did not respond to agent plus interferent

6. CONCLUSIONS

Conclusions are based solely on the results observed during this testing. Aspects of the detectors other than those described were not investigated.

Civilian first responders and HAZMAT personnel use Immediate Danger to Life or Health (IDLH) values to determine levels of protection selection during consequence management of an incident. The HAZMATCAD units in High Sensitivity Mode were able to detect HD, GA, and GB at concentrations close to the JSOR and IDLH values but with exposure times up to 4 min. The units in Fast Mode detected HD at approximately the JSOR value in <3 min exposure time. However, in Fast Mode the units were too inconsistent in their ability to detect either GA or GB at the JSOR and IDLH levels. The HAZMATCAD units were unable to detect HD, GA or GB at the AEL concentrations.

Humidity changes did not appear to cause adverse effects on the HAZMATCAD except that unit A had problems at 90% RH for both GA and GB. However, the detection capabilities of the units were degraded at the high and low temperature extremes. In cold temperatures, the units were unable to detect GA in Fast or High Sensitivity Modes and could only detect HD in Fast Mode with Unit B. Cold temperatures increased the time required for the instruments to recover from agent exposures. High temperatures (50 °C) increased the response times to simulant and higher agent concentrations were required for alarm response.

The unreliable and erratic behavior exhibited by the HAZMATCAD units created unusual and special challenges during the evaluation. Even though field test showed no false positive response for agents and laboratory interference tests showed only one false positive response, test results suggest that the HAZMATCAD in its current configuration cannot be used effectively for CW agent detection. These detectors appear to be unresponsive to many commonly found substances used in the field and laboratory interferent tests. However, during these interference evaluations the detectors were slow to respond to their simulant check and even slower to clear down after the simulant alarm. The laboratory interference testing indicates that units were unable to consistently detect and identify the CW agents in the presence of the interferent vapors. In addition, the units were severely degraded after the field tests.

The inconsistent performance and the effects of extreme temperatures on the detectors that were observed throughout the evaluation severely limit the usefulness of this version of the HAZMATCAD as a warning device.

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